

Effect of recycled natural water treatment sludge and biochar on the mechanical performance and hydration kinetics of Portland cement composite

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the degree of **Master of Engineering (Research)**

under the supervision of Prof. John Zhou

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Samuel De Carvalho Gomes declare that this thesis, is submitted in fulfilment of the requirements for the award of Master of Engineering (Research), in the School of Civil and Environmental Engineering at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Abstract

Water treatment sludge (WTS) management is a growing global problem for water treatment plants (WTPs) and governments. This research examines the application of natural WTS and thermally modified sludge (WTS-biochar) as a construction materials ingredient by converting a waste by-product to a value-added product. Important aspects such as the physicochemical interaction of the sludge/biochar with the Portland cement, the hydration kinetics of the cement paste and the mechanical behaviour of the composite were carefully studied. The results show that for 1-2% of WTS addition, the compressive strength and heat evolution of the cement paste was well maintained being close to the reference specimen after 28 days of curing. However, for sludge addition above 5%, a delay in the hydration reaction was observed, together with about 25% reduction in compressive strength at 28 days of curing. The mineralogical and thermal analysis showed decreasing portlandite content and increasing calcite in the WTS-amended composites. Scanning electron microscope analysis demonstrated that the addition of sludge induced more porous and weak surface structures compared to the reference specimen. The thermally modified WTS (biochar) show an improvement in material kinetics and mechanical properties. The mineralogical, thermal and microscopic analysis shows several pieces of evidence of pozzolanic activity of the biochar. The samples with 2% and 5% WTS-biochar showed higher heat release than the reference material. Specimens with 1%, 2% and 5% WTS-biochar showed a slightly higher compressive strength at 28 days compared to the reference material. As a result of all these findings, this project has shown strong indications that WTS can be promoted as a sustainable and alternative resource for construction materials with less environmental impacts as well as economic savings.

Keywords: Water treatment sludge; Construction materials; Biochar; Cement mortar; Pyrolysis